Does the Ozone Hole Threaten Antarctic Life?

Early evidence is just coming in; so far, the answer is far from clear and investigators are divided

OVER THE PAST FEW YEARS atmospheric chemists have been charting the waxing and waning of the Antarctic ozone hole, trying to discern its mechanisms and predict what it portends for the temperate zones. Radiation biologists have been trying to calculate the number of skin cancers likely to result if the stratospheric ozone layer thins over, say, Kansas. But lost in all the publicity surrounding the ozone hole has been what effect, if any, it is having on the biota that live right under it—the plants and animals that eke out an existence in the hostile conditions near the South Pole.

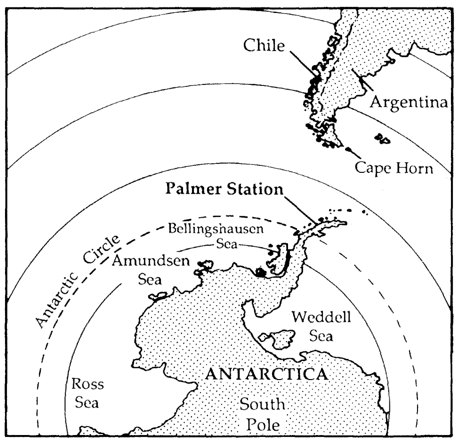
Two years ago the first researchers made the 5-day trek to Palmer Station at the tip of the Antarctic peninsula, some 600 miles south of Cape Horn, to try to find an answer to that question. A few more followed last season, and more are slated to make the journey this year as part of a new National Science Foundation (NSF) program.

The questions are twofold. When the ozone hole appears each September at the start of the austral spring, more biologically damaging ultraviolet radiation penetrates through to the earth's surface—but how much? And what is it doing to the fragile ecosystems at the literal end of the earth?

Preliminary results are just coming in from last season's research at Palmer Station. So far, the evidence on the second question is open to interpretation, and the investigators are poles apart, with some predicting minor effects while others forecast disaster.

At the outset, at least, the investigators are not concerned about terrestrial plants and animals, essentially because there are so few of them. In terms of animals, only microorganisms and invertebrates survive on that desolate, ice-covered continent. Plant life, too, is restricted to algae, mosses, lichens, and just two vascular species. But the oceans, by contrast, are some of the richest ecosystems on earth—and that is where research is focused.

Since the ozone hole was first reported in 1985, the fear has been that the added wallop of ultraviolet radiation each austral spring would harm phytoplankton, the microscopic free-floating algae that form the basis of the marine food chain, with poten-



tially devastating effects. Enough ultraviolet radiation can kill phytoplankton, research in the tropics has shown; lesser amounts will slow photosynthesis. And if Antarctic phytoplankton are affected, the argument goes, then so too will be krill, the tiny animals that feed on them, and then fish, seabirds, seals, and whales.

Any effects will depend on how much ultraviolet radiation is getting through the ozone hole each austral spring, a topic about which surprisingly little is known. Atmospheric scientists have a good fix on the extent of ozone depletion over Antarctica each year—in 1987, the worst year to date, ozone levels over Antarctica declined by 50%, and in 1988, because of milder temperatures in the stratosphere, by just 15%. But how that translates into an increase in the biologically damaging part of the ultraviolet spectrum, known as UV-B—which is also the part of the spectrum most affected by a decrease in stratospheric ozone—is not at all clear.

Last year University of Chicago geophysicists John E. Frederick and Dan Lubin recorded the first real measurements of an increase in ultraviolet radiation on the earth's surface due to the ozone hole. Although the 1988 ozone hole was relatively shallow, the incident ultraviolet radiation dose at Palmer Station was clearly up in September and October when the hole was at its peak. "In October, we picked up radiation levels typical of those at summer solstice," says Frederick. "It was like summer coming 2 months early."

Pointing out that the severity of the hole tends to run in 2-year cycles, Frederick predicts that "next year the hole will be back with a vengeance." During the 1987 ozone hole, he calculated that the incident ultraviolet radiation dose in Antarctica at least doubled. If this pattern repeats itself, then the 1989 spring flux seems certain to exceed that of summer solstice.

What is particularly worrisome, says Deneb Karentz, a marine biologist who studies radiation effects at the University of California at San Francisco, is that this increase in ultraviolet radiation "is so sudden and occurs at a time when organisms are emerging from the dark winter period and thus have not had time to adapt to the sun being up." Adds Sue Weiler, who until recently coordinated ultraviolet radiation effects research at NSF: "For phytoplankton, it would be like a Norwegian going to the Mediterranean over Christmas vacation."

How severely Antarctic organisms are affected will depend not only on how quickly they can adapt but on whether the dose they receive each spring is close to their tolerance, says Frederick. "For humans, our tolerance is far higher than what we are exposed to. But that may not be true for organisms in Antarctica," which evolved in the presence of little ultraviolet radiation.

For phytoplankton, the critical measurement is not incident ultraviolet radiation but how much is penetrating the water column where it could curtail photosynthesis—which essentially determines how much food there is for krill and other zooplankton—or cause other damage.

Contrary to some earlier assertions, ultraviolet radiation does penetrate the water column "to depths that could have ecological significance," says Raymond C. Smith, an oceanographer at the University of California at Santa Barbara—to 10, 20, or perhaps 30 meters on a bright day if the water is clear. If the water is turbid or the sky cloudy, ultraviolet penetration is blocked in the first 5 meters or so.

These estimates are crude, Smith and others are the first to admit, because underwater penetration of ultraviolet radiation is notoriously difficult to measure. Smith hopes to get a better fix on it this coming austral spring when he tries out his new monitor at Palmer Station. But even with those measurements in hand, sorting out the actual dose phytoplankton are receiving will be difficult, as it is confounded by mixing in the water column, which can move the free-floating algae up to the surface or down, out of reach of the penetrating rays. Says Smith: "The game goes both ways."

On this much the investigators agree:

"If anything happens to krill, the whole ecosystem will collapse."

—Sayed El-Sayed

When the ozone hole is deepest, photosynthesis would be expected to decline. But they part company on how big the actual decline is and on what it portends for the rest of the marine ecosystem.

The most dire predictions come from Sayed El-Sayed, a phytoplankton ecologist at Texas A&M University, who in 1987 alarmed his colleagues with reports about the imminent demise of the Antarctic marine ecosystem. Working with phytoplankton in aquaria outside of Palmer Station that were equipped with filters to let in varying amounts of ultraviolet radiation, El-Sayed found a dramatic two- to fourfold decrease in photosynthesis from just a small increase in ultraviolet radiation.

It turns out, El-Sayed now admits, that his initial calculations were wrong. He thought he was dosing the phytoplankton with just a 6% increase in ultraviolet radiation when in fact it was a 50% increase over ambient conditions, which were 100% higher than normal during the 1987 hole.

"My dire predictions still hold," insists El-Sayed, who says that the decline in photosynthesis he documented was real even if the initial dose calculations, which were subsequently corrected, were off. "If these experimental results are true, and indeed they are, then phytoplankton, which constitute the base of the whole food chain, will be severely undermined. Krill depend on phytoplankton, and if anything happens to krill, the whole ecosystem will collapse."

Osmund Holm-Hansen, director of polar research at Scripps Institute of Oceanography, disagrees. Holm-Hansen predicts minimal effects on phytoplankton productivity. His data are based on experiments performed in incubation bottles in the water column at varying depths, an approach El-Sayed was prevented from using because of icy conditions. Holm-Hansen is thus measuring the effect of the total ultraviolet radiation dose during the ozone hole and not the added flux caused by the hole.

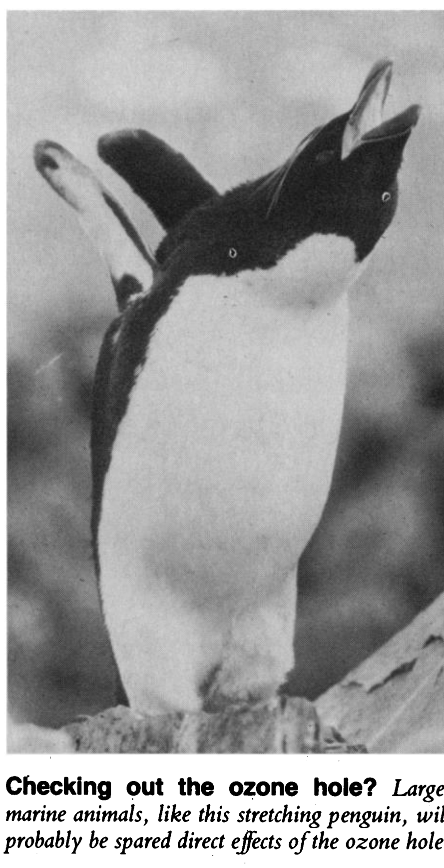
Phytoplankton photosynthesis declined about 15 to 20% in the top 1 meter of the water column during the 1988 ozone hole, says Holm-Hansen, but that decline "fell off exponentially" with depth. "The greatest depth I noticed any significant reduction was 10 to 15 meters," says Holm-Hansen.

All of which leads Holm-Hansen to conclude that "the effect on overall primary productivity in the ocean in the Southern Hemisphere is fairly small. I don't see any scenario in which there would be a catastrophic effect. I am positive there will not be a collapse of the southern ecosystem."

Others investigators are less willing to extrapolate. Weiler, for one, points out that Holm-Hansen did his experiments during the mild 1988 ozone hole, and that "there may be more of an effect from UV if the hole gets deeper and lasts longer," as it is expected to do next year. Smith suspects that the truth may lie somewhere in between the predictions of El-Sayed and Holm-Hansen. But he wants to study photosynthesis declines in natural populations, not in phytoplankton in incubation bottles, before he ventures a guess. "There are lots of uncertainties in attempting to extrapolate experimental results to the environment."

Nor is photosynthesis the only thing to worry about. The problem is that phytoplankton could carry on normal or somewhat diminished photosynthesis and yet, because of ultraviolet damage to their DNA, be unable to divide—something these experiments would be unable to detect. Holm-Hansen, for one, suspects that the biggest danger from ultraviolet radiation may in fact be DNA damage.

The good news, says Karentz of UCSF, is that phytoplankton, like other organisms, have evolved mechanisms to repair DNA damage. In the dozen or so phytoplankton species she has tested to date at Palmer Station, she has found that they rely on a mechanism known as photorepair: in some unknown way, they use higher wavelength ultraviolet radiation, UV-A, to fix what UV-B has torn apart.



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Checking out the ozone hole? *Larger marine animals, like this stretching penguin, will probably be spared direct effects of the ozone hole.*

"I am positive there will not be a collapse of the southern ecosystem."

—Osmund Holm-Hansen

However, the ability to handle ultraviolet radiation varies dramatically from species to species, Karentz says. Some phytoplankton are quite tolerant, while others are exquisitely sensitive and can't survive any ultraviolet radiation.

"Phytoplankton have a wide range of responses to ultraviolet radiation," says Karentz, who thinks that they may also have protective compounds—essentially, natural sunscreens—to block out harmful ultraviolet radiation, as many tropical organisms do. "I don't think we are going to see one whole part of the food chain wiped out." What is more likely, she suspects, is that the ozone hole will lead to a change in species composition as more tolerant species replace the sensitive ones. The implications for the rest of the food chain are difficult to judge. "If some species die out and others replace them, will it make a difference in the feeding behavior of krill? We don't have a clue."

Ted DeLaca, head of polar research at NSF, adds a cautionary note: "It is way too early to say what the consequences of the ozone hole will be." Indeed, investigators will be taking a second crack at these and other questions next season.

"It was fortunate for us to get a breather this year, to develop some methodologies and get some preliminary data," says Weiler. "That means we will be in a better position to study the hole next year" when it is expected to be far deeper.

"If the ozone hole had to develop somewhere, one would hope it would be over Antarctica," Weiler adds, because it gives investigators a chance to work out the basic mechanisms of ultraviolet radiation damage in a setting in which the impact may be relatively small, simply because most of the organisms are underwater where they are somewhat protected. "Antarctica provides a laboratory to help us predict what might happen if ozone depletion worsens in the Arctic and at temperate latitudes."

■ Leslie Roberts